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The Effect of Small-Scale Ocean Fluctuations on Ocean Acoustic Transmission

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LONG-TERM GOALS

To connect the results of sound transmission and scattering experiments to known or hypothesized structures within the hydrosphere, such as internal waves or microstructure, with account taken of ocean anisotropy, inhomogeneity, and the sound channel.

OBJECTIVES

Use theoretical techniques to evaluate expected acoustic fluctuations in propagation through thousands of kilometers of ocean internal waves for use in comparing with experiments carried out with acoustic sources having frequencies of a few hundred Hertz and below.

APPROACH

We have simulated realizations of oceans filled with internal waves, and have calculated acoustic fluctuations by use of the paraxial approximation, and three calculational techniques: geometrical optics (ray integration), multifrequency parabolic-equation solving, and numerical integration based on formulae derived from the path-integral technique. Flatté is a professor of physics with more than 25 years of experience in ocean acoustics. Vera is a physics graduate student who received his Ph.D. during this period.

WORK COMPLETED

Extensive parabolic-equation numerical simulation of 1000-km, 250-Hz propagation through statistical internal waves were used to calculate acoustic fluctuation quantities with the minimum of assumptions: travel-time variance, average travel time (bias), vertical coherence functions, and pulse spreads. The fluctuation results were compared with calculations of the same quantities by means of integrals along unperturbed rays derived from the path-integral technique.

Geometrical-optics ray trajectories were followed through realizations of internal wave fields that were, on the one hand, frozen, and, on the other hand, allowed to propagate in a normal manner. The results of the two cases were compared.

RESULTS

The parabolic-equation simulations are known to be accurate for this problem. The ray integrals for all quantities except the travel-time variance failed drastically beyond about 400 km.

Under conditions in which a ray behaves with a great sensitivity to initial conditions, the difference between frozen and unfrozen internal waves at a source-receiver range of 1000 km is many hundreds of meters in depth. For cases in which the ray does not exhibit great sensitivity, the differences are only a few meters.

IMPACT/APPLICATIONS

Present tomography work is based on travel-time variance. There had been hopes that long-range tomography would be able to use other observables by comparing observations with easily calculated ray integrals. Our results show that use of bias, vertical coherence, and pulse spread will require extensive computer-intensive simulations, making them much more difficult.

It has long been held that, because the speed of sound waves is so much larger than the speed of internal waves, the frozen hypothesis is accurate. Our results imply that it must be used with care in regions in which the rays are sensitive to small changes in the initial conditions.

TRANSITIONS

None

RELATED PROJECTS

North Pacific Acoustic Laboratory (NPAL) involves measurements over several thousand kilometers. We have worked closely with its team over several years. (web site <http://npal.ucsd.edu>)

PUBLICATIONS

Stanley M. Flatte and Michael D. Vera, Comparison between ocean-acoustic fluctuations in parabolic-equation simulations and estimates from integral approximations, in review at J. Acoust. Soc. Am, April 2002.

Stanley M. Flatté and Michael D. Vera, Internal-wave evolution effect on ocean acoustic rays, in press at J. Acoust. Soc. Am, September 2002.